

WEST AFRICAN COCOA RESEARCH INSTITUTE

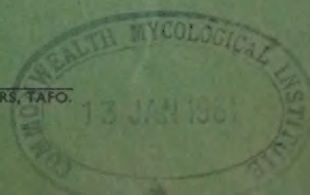
**QUARTERLY PROGRESS
REPORT**

No. 56

TAFO, GHANA.

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WEST AFRICAN COCOA RESEARCH INSTITUTE
TAFO, GHANA

FIFTY-SIXTH QUARTERLY REPORT
OCTOBER-DECEMBER, 1959

Any results recorded in this report should not be accepted as conclusive inasmuch as the report contains interim information only. More complete results are published in W.A.C.R.I. Technical Bulletins and elsewhere.

SENIOR STAFF

Director	J. Lamb
Secretary	H.L. Pugh
Accountant	H.J.S. Mill (went on leave prior to termination 15/12/59)
Assistant Accountant	J.N.A. Hyde (took over as Accountant 15/12/59)
Office Assistant/Librarian	D.J. Ellis (Miss)

TAFO STATION

Division of Entomology	E. Dunn
	P.F. Entwistle (on leave prior to transfer to Ibadan)

	K.B. Armstrong
	M.R. Smith (went on leave 2/12/59)

Division of Pathology	J.W. Blencowe
	A.L. Wharton
	A.A.F. Brunt
	P.D. Turner
	A. Attafuah (on scholarship in U.K.)

Division of Botany	D.R. Glendinning
	R.G. Hurd
	R.G. Lockard (arrived on secondment 16/11/59)

Division of Chemistry	R.H. Kenten
	R.K. Cunningham

Division of Agronomy	T.H.R. Hall
	R.W. Smith (returned from leave 27/10/59)

Statistician	C. de Jonge
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Laboratory Technicians (Electronics)	A.J.H. Arnold
(Spectrography)	J.C. Burridge (returned from leave 5/10/59)

Plantation Manager	H.W.S. Allison (returned from leave 30/11/59)
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Maintenance Engineer	G.O. Hayward
Works Superintendent	E.K. Berko (on leave 21/12/59)

Guide-Demonstrator	F.E. Decker
Station Manager	S.E. Ntim-Kwafo (retired 2/10/59)

Medical Officer	P.K.K. Knudsen (returned from leave 9/11/59)
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IBADAN SUB-STATION

Deputy Director (Nigeria)	T.W. Tinsley
Entomologists	R.G. Donald
	C.K.H. Martini

Pathologists	J.M. Thresh
	D. Kay

Agronomist	J.F. Longworth (on leave)
Mycologist	E.C. Hislop

Plantation Officer	W. Rides
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WEST AFRICAN FUNGICIDES RESEARCH UNIT

Chemist	P.O. Park (returned from leave 19/10/59)
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STAFF MATTERS

Dr. R.G. Lockard joined the staff during the quarter on secondment under an agreement between the Ghana and Canadian Governments. Mr. H.J.S. Mill left on leave prior to termination of contract. Mr. J.N.A. Hyde took over as Accountant.

Dr. P.K.K. Knudsen and Messrs. R.W. Smith, H.W.S. Allison, J.C. BurrIDGE and P.O. Park returned from leave.

Dr. M.R. Smith and Mr. E.K. Berko proceeded on leave.

Dr. T.W. Tinsley visited the then Belgian Congo from 26th September to 25th October 1959.

VISITORS

The main station at Tafo was honoured by visit of H.R.H. the Duke of Edinburgh on 28th November, 1959.

Other visitors to Tafo during the quarter included two officials of the Brazilian Ministry of Agriculture, and Entomologist from Jealott's Hill Research Station, U.K., and a representative of the Hanburg Cocoa Association.

Visitors to Ibadan included an official from the Northern Region Ministry of Education, a representative of the Booker Sugar Company of British Guiana and members of the Chocolate Manufacturers Association of America.

AGRONOMY DIVISION

NOTE ON RE-ORGANISATION

During the quarter the responsibilities of the Agronomy Division were changed. The propagator and the ornamental and forest tree nursery were placed under Agronomy Division, while with the posting of an Agronomist to the Chemistry Division, the Irrigation and cover crops experiments were transferred there.

OLD STATION FARM

YIELD :- Crop Harvested - Old Station Farm October-December, 1959.

Date of Picking	Total Pods		% Pod Dis-carded	Pods Fer-mented	Wet Wt. of beans calculated *(1)	Dry Wt. of beans calculated *(2)
	Har-vested	Dis-carded				
Sept.21-Oct. 2	73,700	5,000	6.9	68,700	13740	5723
Oct.12 -Oct.28	89,000	5,000	6.3	83,400	16680	6952
Nov. 6 -Nov.27	86,700	3,300	3.8	83,400	16670	6947
Dec. 7- Dec.18	47,300	2,600	5.6	44,700	8930	3722
Total	296,700	16,500	5.6	280,200	56020	23344

*(1) Wet weight assessed on the basis of 5 pods to a lb.

*(2) Dry weight " " " " " 12 pods to a lb

TREE MORTALITY - Old Station October-December, 1959.

Month	Trees Destroyed		Total	No. of Seedlings Removed
	Swollen Shoot	Undiagnosed		
1959				
October	26	-	26	15
November	11	-	11	25
December	49	-	49	18
Total	86	-	86	56

SEED GARDEN

One acre contained in plots F63 and F64 and in G52 and G53 were cleared off and planted with bananas for shade in preparation for planting a seed garden in 1960 to produce WAE3 (T85/799 x O.P. Amelonado).

SQUARE MILE

HARVESTING OF EXPERIMENTAL PLOTS

Routine harvesting occupied all personnel of the division during the quarter, most of the crop coming off the trees in November. The Amelonado spacing trial however still carried a considerable crop estimated at 10% of the total. Yields during the quarter are shown in Table A3.

Table A3 : Yield in Experiments - October-December, 1959

Experiment	Plot No.	1959 Oct. - Dec. Pods	1958 Oct.-Dec. Pods	% Increase + or Decrease -
A. Spacing and Pruning	B2	35,900	38,900	- 8%
A. " Extension	B2(a)	9,200	9,500	- 3%
A. Multiplication	B1	36,500	32,700	+ 12%
Amelonado Spacing Trial	J1	121,000	93,400	+ 39%
Factorial Fertilizer Trial	G5	29,700	14,100	+ 111%
and Establishment B1	L2	6,900	7,500	- 8%
" " BII	H1	26,700	29,900	- 11%
Uniformity Trial	G1	106,000	73,500	+ 44%
Amelonado Pruning Trial	P2	7,000	2,800	+ 150%
" Source Trial	G4	9,100	8,800	+ 3%
Shade and Manurial Trial	K1	86,200	100,244	- 14%
Amazon Tree Forming and Pruning	D7	870	-	
Total	-	475,000	511,100	+ 15.5%

OTHER EXPERIMENTS IN SQUARE MILE

An experiment to examine the use of four nurse shade regimes, laid down in the previous quarter, was maintained. The four shade treatments being tested are A. Plantain, B. Banana, C. Tree Cassava, and D. Plantain and Tree Cassava mixture, laid out in a randomized block design with 8 replications. Each plot contains 16 trees. Up to the end of December, the Banana plots have shown the best growth and in so doing have reduced weed growth considerably. Height and girth measurements of the young cocoa seedlings were taken in October.

Agronomy Division is managing the virus Resistance Variety Trial for Pathology Division. To date there have been no death, while maintenance (weeding and control of regenerating vegetation) has been continuous.

Preparations for planting a one-acre corner of Block J with rooted cuttings in 1960 started during the quarter. Banana nurse shade was planted at the end of November. The area will be used for an empirical study of the management of clonal cocoa.

PROPAGATION

Varying amounts of cuttings were rooted for the seed garden, the proposed observations in Block J, for the Botany Division and the Pathology Division. Rooting results are shown in Table A4.

Table A4: Propagation of Cuttings - October-December, 1959.

Selection	No. Set.	No. Rooted	% Success
T63/971	500	452	90
T85/799	585	404	70
Pa7	15	15	100
Na31	15	14	93
Na33	15	9	60
Pa35	15	14	100
Na34	15	9	69
Sc4	15	12	75
ACU85	15	15	100
IMC60	15	15	100

Table A5: Cuttings set during December, 1959.

T79/416	42	P30	120	T65/971	66
E1/70	42	R15	66	ICS39	66
S84/90	42	UCS85	66	Na32	438
Pa35	438	ICS40	66	W41	66

Table A6: Distribution of Pods.

	Amazon F3
Western Region Nigeria Department of Agriculture	81,532
Northern Region Nigeria	2,000
University College of Ghana	1,683
Local Sales (WACRI Staff)	1,500

ORNAMENTAL AND FORESTRY TREE NURSERY

Preparations were started at the end of the quarter to re-stock the nursery which contained a large stock of over-aged planting material. Fagara melanorrhachii ex Belgian Congo and Thevetia sp. seed were sown in trays.

Table A7 : Rainfall - October-December, 1959

Month	1959		Past 21-year means	
	Rainfall (ins.)	Wet days	Rainfall (ins.)	Wet days
October	7.55	22	8.78	18.7
November	2.98	12	4.07	11.2
December	2.79	7	2.42	6.2

PATHOLOGY DIVISION

VIRUS RESEARCH

Effect of virus infection on growth and yield of Amelonado and Amazon cocoa.

In Experiment A4 (Quarterly Report No.55) over 80 per cent of the trees graft-inoculated 9 months ago with isolates of the swollen shoot virus (Dawa, New Juaben and Bosomuoso) and 70 per cent of those infected with the cocoa mottle-leaf virus (kpeve isolate) have now shown symptoms. Swellings have been detected in only 8 per cent of trees similarly graft-infected with the Bisa isolate. The canopy of many trees infected with severe isolates has deteriorated so that each infected plot gives the appearance of a small virus outbreak.

In Experiment H2 over 75 per cent of graft-inoculated Amelonado trees are now visibly infected but only 30 per cent of the Amazon trees have shown symptoms. The trend (Quarterly Report No.55) in which symptoms were more readily detected in unshaded Amazon cocoa has persisted during the last quarter.

In November and December all treatment plots of the joint W.A.C.R.I./Division of Agriculture experiments (Quarterly Report No.55) received applications of gamma - B.H.C. which was applied at the rate of 4 oz. insecticide per acre on each occasion. The plots continued to respond favourably to the clearing of undergrowth and weeds. At Ampem many infected trees died on both the sprayed and unsprayed plots, but at other sites fewer deaths were recorded.

Seedling growth rate experiments have shown that in contrast to results obtained in Nigeria (Quarterly Report No.55), extensive lateral root necrosis results from infection by virulent Ghanaian isolates of the swollen shoot and mottle-leaf viruses. In one experiment (See Table P1) simultaneous infection with the unrelated Kpeve and severe New Juaben isolates caused a great reduction in

Table P1

Dry weight distribution (in g.) 6 months after infection
(Mean of 30 plants per treatment).

ISOLATE	LEAVES	STEMS	TAP ROOT	LATERAL ROOTS	TOTAL
Healthy	3.32	1.58	0.78	0.36	6.04
Kpeve	1.87	0.59	0.63	0.18	3.27
New Juaben	1.18	0.76	0.71	0.14	2.69
Kpeve and New Juaben	0.61	0.56	0.59	0.05	1.81

lateral root growth although each virus alone also caused a substantial reduction (see Table P2).

Table P.2

Percentage reduction relative to healthy controls

ISOLATE	LEAVES	STEMS	TAP ROOT	LATERAL ROOTS	TOTAL
Kpeve	43.7	62.7	19.2	50.0	45.9
New Juaben	64.5	51.9	21.7	61.1	55.4
Kpeve and New Juaben	81.6	64.6	24.4	86.1	70.0

Attempts to graft-transmit a virus from material collected from suspected virus-infected trees at Giehun, Sierra Leone, have given indefinite results. Virus-like symptoms (narrow chlorotic vein-banding on hardening flush leaves) developed on the first flush leaves produced after grafting but the subsequent flush was symptomless. Attempts to transmit a virus from the material collected at Giehun and from grafted seedlings with P. njalensis and Ferrisiana virgata have been made and the results are awaited.

Insect transmission studies

Attempts to transmit the Kpeve and severe New Juaben virus isolates with mealybugs tentatively identified as Pseudococcus comstocki (Kuwana) have failed. These 2 Ghanaian isolates (which were selected as representatives of the cocoa mottle leaf and cocoa swollen shoot viruses) therefore appear to differ from the cocoa virus in Trinidad for which P. comstocki is a vector (Kirkpatrick, Rep. Cacao Res., Trin., 122, 1945-1951). This was examined further by graft-infecting cuttings of ICS clone numbers 7 and 60 clones on which symptoms of strains A and B of the Trinidad virus have been described (Baker and Dale, Ann. appl. Biol. 34, 60, 1947), with the Ghanaian isolates. On both clones the severe New Juaben isolate produced a transient red vein banding on flush leaves and occasional chlorotic vein-fleckings along the minor veins of mature leaves. Infection also caused root, stem and stem-tip swellings. The Kpeve isolate induced a transient red mottle on the flush leaves of both clones but no distinctive symptoms were observed on hardened leaves.

Symptoms of the Ghanaian isolates on these clones differ considerably from the reported symptoms of strains A and B of the Trinidad virus, which suggests that different viruses occur in Trinidad and West Africa.

STUDIES ON BLACK POD DISEASE

Strains of *Phytophthora palmivora*

During October, visits were made to Southern Cameroons, Fernando Po and French Cameroons, and extensive collections of disease samples made from widespread localities. Details of the visit are available in a full report. Subsequent examination of the isolates has shown that the dominant pathogen in these countries is very similar to that found in Nigeria (see previous quarterly report). One isolate, from Isobi in Southern Cameroons, was identical with the typical Tafo isolate.

An experiment has been started to attempt to distinguish between isolates of P. palmivora by serological methods.

Fungicide spray control trials

Final records for the experiment on control of black-pod disease by mineral oil are awaiting analysis and are summarised in Table 3.

Table P3

Disease control by mineral oil: incidence of black pod.

Spacing	Replicate number	Total Pods	No. black-pods	% black-pod	
8 x 8	3	2822	396	14.0	Treated
8 x 8 P	2	1644	210	12.8	
10 x 10	1	859	105	12.2	
10 x 10 P	4	2338	175	7.5	
12 x 12	2	1200	79	6.6	
12 x 12 P	3	2436	142	5.8	
Total	15	11299	1107	9.8	
8 x 8	2	1545	384	24.9	Control
8 x 8 P	3	2462	300	12.2	
10 x 10	4	4005	587	14.7	
10 x 10 P	1	1270	57	4.5	
12 x 12	3	3521	476	13.5	
12 x 12 P	2	867	29	3.3	
Total	15	13670	1833	13.4	

P = pruned to 1st jorquette.

Recording of diseased pods on experiments OSX1 and OSX2 has now ceased and the trials will be terminated when the remaining crop is harvested during January 1960. Levels of pod disease have again been negligible on the two trials. The trials were also designed to allow comparison of treatment effects, on total yield based on the mean of two years' pre-treatment and two years' treatment data. These analyses are not yet complete.

Resistance and tolerance.

All available pods for planting the six-acre trial at Mpraeso have now been sent to Pankese cocoa station and the beans established in "whale-hide" pots. There have been unfortunate failures in setting from hand-pollinations made late in the flowering season, particularly those including S27 as a parent. S27 proved a particularly resistant type in the 1st Clonal Trial and further pollinations will be made this year for planting crosses in 1961. A single year's detailed records of black-pod disease are now available from the 2nd clonal trial. The system of leaving diseased pods on the trees in this trial after recording and labelling each one has raised the incidence of "black pod" to an extremely high level. Main crop harvesting is not yet complete but from experience of yields in previous years the "black pod" data collected in 1959 will represent wide differences in susceptibility between the various clones. Clones R15 and D70

gave a potential yield of 2000 lbs. and 1800 lbs. respectively in 1958; the total number of "black pods" from the 96 trees of each clone in 1959 were 1293 on R15 and 148 on D70. Because all the trial area at Mpraeso cannot be planted in 1960 the opportunity will be considered of including crosses from the most resistant type in the 2nd Clonal Trial (possibly D70) for planting in 1961.

The trial area is now cleared and ready for planting. Tree cassave has been established as temporary shade. The spot plan allows a randomised block design of 19 selections in 10 tree plots replicated 8 times. As all the guard rows will be clone A12-selfed, plots for this clone within each replicate will be selected from guard-row trees. There will probably be sufficient buddings (80) of clone Laf1 7 to plant as a complete variety in 1960. Buddings of clone 12B (from Cameroun) will be planted in five extra observation plots.

Importance of "black pod" disease in Ghana

Summaries and analyses have been made of five years' crop data (1954-1958) collected on 23 "Capsid Yield-Recorded Units" of the Ministry of Agriculture. These units (12 in Ashanti, 11 in Southern Ghana) are the first plots of farmers' mature cocoa on which the control capsid attack by the low-volume application of insecticide sprays was demonstrated. It was shown that the distribution of pod disease over the five years fitted a normal curve and they can be accepted as a random sample for the assessment of pod disease on farmers' cocoa in the two main-producing areas, Ashanti and Southern Ghana. The data includes records for nearly 4,500,000 pods collected from a total of 163.9 acres of cocoa. Incidence of pod disease during the period reviewed averaged 29 and 26 per cent of the total crop for the plots in Southern Ghana and Ashanti respectively. However, pod disease records were split into infections of ripe pods and immature pods. The latter are a complete loss whereas many of the former yield fermentable beans. The absolute loss of crop was taken as the number of immature diseased pods plus 55 per cent. of the diseased ripe as a proportion of the total crop harvested. Losses on the Southern Ghana plots were greater than those on the Ashanti plots where there were more diseased ripe than diseased unripe pods. These are minimum losses for the two regions because:

- (a) the data does not include records of black-pod on small cherelles;
- (b) farmers themselves harvest less frequently than the regular monthly harvests carried out on these experimental plots and the proportion of diseased ripe pods lost may then be much greater than 55 per cent.

Each unit consisted of two plots, one sprayed against capsids and one unsprayed control. The average yield during the four years

following the one in which spraying commenced increased to 542 lbs. per acre (6504 pods); an increase of 140 per cent. over the first year's crop which had already set and was not affected by the initial sprays. This increase in total crop was accompanied by an increase in numbers of pods attacked by black-pod disease. The relation between these two increases is linear and regression lines can therefore be fitted to the data to determine the proportion of an increasing crop which it is expected will be attacked by black-pod disease. Regression coefficients for the Ashanti and Southern Ghana Units were virtually identical, 0.280 and 0.290 respectively. That is, in the two main producing areas it is expected that for every increase of 1000 pods following capsid control 280 to 290 will be attacked by black-pod disease. These figures are almost constant for any one year and are independent of the seasonal incidence of black-pod disease.

The main objects of analysing this survey data were to obtain estimates over a period of years of the importance of black pod in Ghana and to determine if capsid control would result in such increased numbers of pods lost from "black-pod" that spray control methods would become economic.

The evidence now suggests that it will still be uneconomic to apply fungicides unless they are highly effective and control can be achieved by low cost methods. A limited number of sprays concentrated on the mid-crop outbreak from May to July, instead of sprays applied at more extended intervals for eight months might, if effective, reduce costs substantially. Experiments on these lines are starting in 1961 on those of the 23 capsid plots which the survey data showed to be yielding at least 450 lbs. dry cocoa per acre and subject each year to a disease incidence of at least 20 per cent.

A GALL DISEASE OF COCOA IN GHANA

The West African gall disease (Quarterly Report No.55) has been transmitted from galls on mature trees and those produced on artificially-infected seedlings by various mechanical inoculation methods and by nymphs and adults of the mealybug species Pseudococcus njalensis Laing. It has been shown that cocoa half beans are very susceptible to infection and have therefore been used as test plants in mechanical and insect transmission studies. On some inoculated seedlings secondary galls, which have the same structure as primary galls, have developed in the axil of the first leaf or first pair of leaves. Although the field survey (an account of which has been published in Commonwealth Phytopathological News, 5, 61, 1959) has shown that the gall disease is at present of little economic importance in Ghana (Quarterly Report No.55), the case with which the disease has been transmitted

in laboratory tests and the similarity of its galls with those of the important cushion gall disease in the Western Hemisphere indicates that it must be considered a disease of potential importance. For this reason, it has been recommended that all galls found on cocoa should be removed and destroyed.

Neither nematodes nor other gall-forming pests have been found in gall-tissue and transmission of the disease by mechanical methods in the absence of such pests has indicated that the disease is of pathogenic origin. Fungal hyphae have been observed in some stained sections of galls although only Botryodiplodia theobromae Pat. and Calonectria rigidiuscula (Berk. & Br.) Sacc. have been isolated occasionally from gall tissue. Grafting and insect transmission tests have failed to demonstrate systemic infection in gall-bearing trees and seedlings, and filtrates from young seedling-gall extracts passed through a Seitz filter (grade EKS sterilizing asbestos film, Graffin & George, Ltd.) were non-infectious. Moreover, when gall exudates were centrifuged for 10 minutes at 8,000 r.p.m. and the precipitate and supernatant then assayed for infectivity, only the precipitate was found to be infective. The results of these preliminary experiments indicate that the disease is of bacterial origin and attempts to isolate a pathogenic bacterium are in progress.

Attempts to transmit the disease to other hosts has failed but susceptibility has been demonstrated in Amazon, Trinitario and Criollo cocoa. Galls identical with those produced on Amelonado seedlings have developed on seedlings grown from inoculated half beans obtained from open-pollinated pods on female parents T16/615, T2, ICS1/738, ICS8/109, ICS25/119, ICS89/106 and Colombian types 194/24 and 195/182.

Enlarged gall-like cushions observed on some "male" trees and very old trees of Trinitario and Cundeamor origin are not thought to be symptoms of the transmissible gall disease.

ENTOMOLOGY DIVISION

JOINT WACRI/DIVISION OF AGRICULTURE CAPSID CONTROL TRIALS

Capsid Studies

In Ashanti the trials with Endrin, Aldrin and Gammalin at dosages approximately in inverse proportion to the cost (see Quarterly Report No.50) are continuing. The fourth annual retreatment sprays were carried out in December. Endrin still appears to be holding its own in giving the best control of capsids with Aldrin next followed closely by Gammlain. More caterpillar damage to flush growth, however, was noted in the Endrin treated plots. In the Marmara pod damage assessments, the Gammalin and Aldrin

Units showed a higher incidence of damage than in the Endrin and Control Units.

Capsid Spraying - Pyrethrins

A joint experiment with the Division of Agriculture on the use of Pyrethrin sprays as a future means of overcoming possible capsid resistance to chlorinated hydrocarbon insecticides, gave poor control with high costs. Four, two-acre plots, matched for pretreatment capsid attack, were used for each treatment. A water-miscible Pyrethrin formulation was applied at (a) 0.4% active ingredient (a.i.) in 5 gallons/acre, (b) 0.16% (a.i.) in 5 gallons/acre and (c) 0.16% (a.i.) in 10 gallons/acre by mistblower. Numbers of damaged trees were lower in the untreated area for all post-treatment counts.

Laboratory screening has also shown that capsids are not sufficiently susceptible to pyrethrins at the present cost of application. Addition of piperonyl butoxide as synergist does, however, increase susceptibility by a factor of seven under laboratory conditions.

There is no indication that resistant strains of capsids are becoming established under the present capsid spraying programme.

MEALYBUG STUDIES

Oyoko

This experiment which was commenced in November, 1956, was terminated at the end of December, 1959.

The principal aim was to reduce the incidence of swollen shoot by controlling the vector insects of the disease by destruction of the attendant ant population. A comparison was also made of removal of infected trees and removal of infected plus contact trees.

The results of the ant and mealybug counts during the first two years (Rep. W.Afr. Cocoa Res. Inst. 1957-58 and 1958-59) were very encouraging; the incidence of swollen shoot fell to 29% of pretreatment levels in the treated area which included removal of contact trees. Since January, 1959, i.e. 4 months after the last Dieldrin application, numbers of visibly infected trees in this treated area have increased to pretreatment levels. A similar, but less well marked increase in the number of trees cut out, has also occurred in the other plots. A striking increase in the numbers of minor pests, particularly lepidopterous borers, followed mistblower application of 1 lb. Dieldrin per acre to foliage and trunks. This work will be published in detail elsewhere.

Bunso Area

Ant and mealybug populations have fallen to a low level on all treated plots. Mealybug populations have also decreased somewhat in non-treated areas.

LABORATORY ASSESSMENT OF INSECTICIDES

Final laboratory analysis of several commercial gamma-BHC formulations after 24 hours degradation at 30°C indicates that there is no difference between them when compared at the LD50 using Distantiella theobroma (Dist). The slopes of the regression lines were also directly comparable.

PERSISTENCE OF INSECTICIDES

Investigation is being made of the persistence of the chlorinated hydrocarbons, gamma-BHC, Aldrin and Endrin at 2 dosage levels, after application to mature cocoa in the field. Preliminary work on various techniques for the extraction and concentration of surface residues on leaves has been carried out and a satisfactory method has been established. Application of the sprays will be made in January when little rain-fall is to be expected. Estimation of persistence will be made at 24 hours, 3 days, 7 days and 14 days, using the glass vial technique with Drosophila melanogaster Meig. as bio-assay material and with caged capsids in contact with treated leaves. Chemical assay will also be carried out.

POD FUMIGATION

Following the success of fumigation of pods in sacks with a 50/50 mixture of ethylene dichloride and carbon tetrachloride (Quarterly Report No.52, p.9), it was hoped that by use of Propylene Oxide, control of both Phytophthora spores and mealybugs be achieved. A low concentration of Propylene oxide, (0.16g/litre) gave one hundred per cent mealybug mortality but only 60% bean germination, and above this level a rapid fall off in germination occurred. Satisfactory control of Phytophthora was obtained only at concentrations which inhibited all bean germination.

MINOR PESTS

These studies have been terminated in Ghana.

LEAF-EATING LEPIDOPTERA

A survey of leaf-eating Lepidoptera on cocoa at W.A.C.R.I. is continuing.

SHADE V. NO SHADE EXPERIMENT ON ESTABLISHED SEEDLING COCOA

In the 1958-59 Annual Report it was stated that it was desirable to know what the effects of shade removal would be on insect populations. An experiment has now been started, in which the insect populations on cocoa nursed by cassava shade, and on cocoa from which the shade has been removed approximately one year

after planting are being studied quantitatively. The statistical design of the experiment is a 6 x 6 latin square.

BOTANY DIVISION

UPTAKE OF RADIOACTIVE PHOSPHATE BY COCOA

Uptake of radioactive phosphate from the soil by seedlings was determined. Radioactivity was present throughout the 10 month-old plants within 24 hours. In contrast to the rapid uptake and distribution in seedlings only low uptakes were obtained when the last mature flush of leaves of mature trees was painted with a solution containing radioactive phosphate and there was only a limited translocation out of the leaves. However, radioactivity could be traced in the beans of nearby developing pods within 3 days of application. Pods absorb phosphate painted on the husk at all stages of their development, but little phosphate was translocated into ripe pods when the radioactive solution was applied to the soil or painted on the leaves.

PHYLLOTAXY OF CHUPON MATERIAL OF COCOA

The spiral in which the leaves are inserted up the stem of a cocoa chupon may be either left or right handed. On the main stem of 120 twelve-month old seedlings it was found that 54 had a left hand spiral and 66 a right hand spiral. The direction of the spiral sometimes changes along the length of the chupon at the point of insertion of a lateral branch. The lateral itself, if it is a chupon, may spiral in either direction without relation to the spiral of the main branch.

The phyllotaxy formula is either $2/5$ or $3/8$ neither formula giving a perfect fit. If every 5th or 8th leaf is marked a slow spiral is followed which on a chupon with a left hand spiral is right handed for a $2/5$ formula and left handed for a $3/8$. The reverse is true on a chupon with a right handed spiral. In all cases approximately 80 internodes are passed before this secondary spiral has completed one revolution. It is suggested that this represents a gradual twisting of the growing point itself and until the direction of this has been observed it is impossible to say which of the two formulae is correct. On the basis of the production of 5 branches at the jorquette the $2/5$ phyllotaxy is more likely.

CHEMISTRY DIVISION

SOIL FERTILITY

Field Experiments

Harvesting and maintenance continues in all fertilizer field experiments.

The 2⁴ NPKMg nutritional pot experiment mentioned in Quarterly Report Nos. 54 and 55 ended. A highly significant response to nitrogen has been obtained.

Laboratory Work

The study of forest soil nitrification and other laboratory investigations mentioned in previous reports continue.

IRRIGATION

The pilot irrigation trial, which commenced in December 1957 continued. During December 1959, the original system of hand watering using basin irrigation, was superseded by the use of an overhead sprinkler system, using an oscillating spray line.

An irrigation experiment on mature Amelonado cocoa commenced at the end of the quarter. A sprinkler irrigation system is also being used in this plot.

COVER CROPS AND MULCHES

Observations on the performance of the cover crops and the growth of the cocoa seedlings continue.

COCOA PREPARATION

Investigation of the versatility of the 'tray method' of fermentation has progressed. So far this season we have over 400 experimental tray fermentations and we are approaching a better understanding of the effect on the quality of the finished cocoa of variables, such as, batch size, time of year, dimension of tray and drying conditions.

Studies of the fermentation of small lots of cocoa ($\frac{1}{2}$ - 20 lbs.) both in the laboratory and the fermentary continue.

SPECTROGRAPHIC LABORATORY

A method for the analysis of ashed plant materials for copper, iron and manganese has been put into operation. Concentrations of manganese, greater than 2,000 ppm. on an oven dry basis, were found in leaves from the fertilized treatments of the pot experiment described previously. (Quarterly Report No. 50 p. 12).

Calibration continues for the setting up of other analytical methods.

PLANTATION MANAGEMENT DIVISION

PODS HARVESTED:

Table M1: Below is the table showing number of pods harvested during the quarter.

SQUARE MILE:

	Young planted cocoa		Mature cocoa	Total	
	Amelonado	Amazon	Amelonado	Amelonado/Amazon	
October	39,845	-	165,541	205,386	-
November	29,362	-	116,476	145,838	-
December	8,284	-	21,880	30,164	-
Total	77,491	-	303,897	381,388	-

OLD STATION

October	30,885	-	103,621	134,506	-
November	29,665	-	91,568	121,233	-
December	30,657	-	26,065	56,722	-
Total	91,207	-	221,254	312,461	-

I B A D A N S U B - S T A T I O N

VIRUS RESEARCH

Insect Transmission Of Nigerian Cocoa Viruses

The most recent attempts to transmit cacao necrosis virus by insects have involved an aphid from cotton; probably Aphis gossypii Glover which feeds and reproduces readily on soft flush leaves of cocoa. No transmissions have been obtained yet.

Experiments have been done on the effects of starving mealybugs on their ability to transmit some isolates of cacao swollen shoot virus. Preliminary starvation periods of two hours, one hour, 30 and 15 minutes followed by infection feeds of two hours seem to be without effect, as unstarved insects transmitted as well as starved ones. The effect of longer starvation periods up to 24 hours is now being tested.

Tolerance to Swollen Shoot Disease

Eradication measures are the usual ones adopted for the control of swollen shoot disease in West Africa. Other measures including the use of insecticides and resistant or tolerant varieties have

not been adopted, although they have been investigated in preliminary trials at Tafo.

The use of tolerant varieties has not been encouraged because of the possibility of virus spreading undetected in such material. This could then become a dangerous source of infection to adjacent susceptible trees. However, the objection is not valid in two large areas of Western Nigeria where control measures have been abandoned and virus is allowed to spread unchecked in the highly susceptible Amelonado population.

Preliminary experiments on tolerance are being carried out in Nigeria with the 85 W.A.C.R.I., clones, which include Amelonado, Trinitario and Amazon selections. The technique which has been adopted is intended to give a rapid segregation into resistant and tolerant types. It involves grafting several healthy buds of each clone on to seedling Amelonado stocks which are already infected with a virulent isolate of cacao swollen shoot virus from Egbeda in the Ibadan area of mass infection.

The first results have been very encouraging and symptoms have usually appeared on the earliest growth made by the budlings. Four reactions have been distinguished, in order of increasing tolerance:-

1. Very severe symptoms with swellings, leaf discolouration, necrosis, abscission and severe chlorosis of the leaves which remain, e.g. Amelonado clones C20 and C18.
2. Large swellings and obvious leaf symptoms, but little or no abscission and necrosis. e.g. Amazon clone 74.
3. Swellings small, often appearing some months after bud break or not at all. Leaf symptoms not severe and restricted to certain flushes. e.g. Trinitario clone 14.
4. Swelling not formed and the leaf symptoms transient or very mild and restricted to a small proportion of the leaves. e.g. Trinitario clone 23 and Amazon clone 77.

After four months the most tolerant clones have made very vigorous growth and some have as many as 20 large and virtually symptomless leaves. By comparison, the most susceptible budlings are still almost leafless and some have died. These results were with susceptible stocks, which suggest that the differences would have been even greater if the clones had been on their own roots. This possibility is being tested and the budding technique is also being used to investigate the reaction of some of the different varieties grown by Mr. Glendinning in his Nigerian experiments. Tests will also be done with virulent viruses from elsewhere in Nigeria and the aim is to produce vigorous seedlings which will continue to do well even though they are infected with different virulent viruses.

Seeds of known parentage were received from Mr. Glendinning at Tafo in 1958 and 1959. These are being planted in the field in experiments to test resistance and tolerance similar to those being carried out in Ghana (Quarterly Progress Report No.54). However, in the Nigerian experiments the plots of each variety are being split for an immediate virus inoculation. This will permit a rapid assessment of tolerance, and resistance will be measured by the rate at which virus subsequently spreads into the healthy sub-plots.

BLACK POD CONTROL

A. Laboratory Studies

A number of fungicides have been compared using the modified technique described in the Quarterly Progress Report No.55. The various types of formulation, are compared with standard laboratory Bordeaux Mixture for their ability to protect pods against Phytophthora palmivora Butl. These experiments ended with the onset of the dry season. The three proprietary cuprous oxide formulations included in the field trial at Owena were further investigated. Little or no significant difference between the protective effect of the three cuprous oxides was observed, but the standard laboratory Bordeaux Mixture was significantly superior (5% level) to two of them. Copper oxychloride formulations have been proved inferior to cuprous oxide formulations (Quarterly Progress Report No.55) and in the latest experiments four copper oxychloride formulations containing additives intended to supplement their activity were used. The formulations contain :- .

A - 33.5% Cu (as copper oxychloride), 32% Ziram.

B - 37.5% Cu (as COC), 15% Zineb.

C - 50% Cu (as COC), 0.6% Hg (as phenyl mercury chloride)

D - 50% Cu (as COC), Ray-leave, means that % Hg. unknown in proprietary compd. used.

When these formulations were compared (as 0.1% w/v) with standard laboratory Bordeaux Mixture (at 0.05% Cu), formulation D was the most effective, though inferior to the standard and the organic fungicides did not appear to be effective additives. The development of lesions in these end-of-season experiments was not completely satisfactory and the factors causing this are obscure. Thus, further work will be necessary to confirm these results and to elucidate the factors adverse to infection.

It has still not been possible to obtain a satisfactory artificial culture of P. palmivora. In order to maintain a supply of zoospores during the dry season pod-to-pod transfer has been carried out, but even this technique may fail.

The new nozzle has been fitted to the settling tower and calibration completed using Kiton Red instead of Aniline Blue. Uniform deposits were obtained on batches of 12 slides with replicate mean deposits within $\pm 3\%$ and individual slide deposits.

within $\pm$ 5% of the mean deposit. Sprays of standard laboratory Bordeaux Mixture and other fungicides gave similar deposits to those obtained using the dye.

The plant pathologist has co-operated with Mr. P.D. Turner in an inoculation study which will be reported elsewhere.

The Chemist has continued investigations into improved analytical methods for determining fungicide deposits on pods.

Field Studies

The Owena field trial has been completed, and the results analysed statistically. There was great variability in the level of infection in different parts of the site. This variability seriously interfered with the comparison of treatments and no significant differences were detected. However, it is clear that the four fungicides are all effective in Black Pod Control.

In addition to this statistically laid-out trial in Ondo Province a number of demonstration comparisons of the same fungicides were laid out near Ilaro, Araromi and Ife. Plots of about $\frac{1}{4}$ acre were sprayed according to the Ministry of Agriculture and Natural Resources recommendations, and in addition unsprayed control plots were demarcated. Black pod percentages were obtained for the various harvests, but since there was no replication, a formal statistical analysis is impossible. The general conclusion from these block comparisons is that none of the fungicides was obviously inferior to one another, when applied in essentially the same way as the farmer would spray. All gave appreciable reductions in Black Pod infection.

INSECTICIDES

Physical assessment (see Annual Report 58-59) of a further 20% Gamma B.H.C. emulsion designed for capsid control has been carried out by the chemist in co-operation with Mr. R.G. Donald.

STUDIES ON "DIE-BACK" OF COCOA

It has been shown that both macrospores and microspores, of the imperfect stage of Calonectria rigidiuscula (Berk. & Br.) are pathogenic to cocoa tissue and form typical lesions when inoculated by needle. It was found that at dilutions below 2,000 spores per c.c. the percentage of successful inoculations was greatly decreased and only 20 per cent. of the inoculations were successful, using 50 spores per c.c. Lesions caused by dilute suspensions were narrower, as shown by transverse sections of the stem, than those caused by heavy suspensions.

Studies have been made on the incidence and subsequent spread of die-back caused by inoculating the fungus C. rigidiuscula into twigs of virus-infected and healthy cocoa trees using the multiple inoculation technique (W.A.C.R.I. Quarterly Progress Report No. 54). In experiments made on a total of 200 trees in five farms

in Nigeria the percentage of twigs dying back to the point of inoculation on trees infected with swollen shoot disease varied between 26.2 and 37.6, with an average of 32.6. Comparable figures for non-infected trees were 14.2 and 20.3, with an average of 18.2. Further experiments showed that die-back was more likely to occur on trees inoculated in the acute stage of virus infection than in the chronic stage. This is understandable because trees in the acute stage of infection are affected particularly severely by virus, which reduces the size, number and persistence of the leaves and may cause death of the growing points.

At Tafo, Ghana similar experiments were carried out on 36 trees, and after four weeks 36 per cent. of the inoculated twigs had died back on the eighteen virus-infected trees compared with 27.7 per cent. on the controls.

In another experiment the incidence of die-back was found to vary with the virus introduced into the trees:-

Dieback in Healthy Trees and Trees Inoculated with Different Viruses

<u>Type of Virus</u>	<u>Percentage Incidence of "Dieback"</u>
Severe New Juaben	50.1
Kpeve	35.0
Bisa	35.0
Mild New Juaben	18.7
Healthy Control	11.2

The high value recorded for trees infected with the relatively mild isolate from Bisa was probably due to contamination with the severe New Juaben virus which spread into the plot during the experiment.

In all experiments, the spread of the fungus below the point of inoculation was recorded at monthly intervals, as in previous trials (W.A.C.R.I. Ann. Report 1957-58). In the Nigerian experiments the total spread of the fungus in 20 weeks on virus-infected trees was between 5 and 57 per cent. greater than that on the controls. At Tafo, over a period of 8 weeks, there was 66 per cent. more spread of the fungus on virus-infected trees than on controls. The results of the spread of the fungus in trees with different types of virus are given below.

Spread of Dieback in Trees Inoculated with Different
Viruses

Virus Infection	Linear Spread of Fungus in Inches			Cubic Inches of Wood Infected		
	4 weeks	8 weeks	12 weeks	4 weeks	8 weeks	12 wks.
Severe New Juaben	500	750	883	104	112.5	173
Kpeve	262	394	529	70.7	79.2	134.9
Bisa	310	391	507	41.7	45.3	83.4
Mild New Juaben	50	208	259	2.4	18.0	21.4
Healthy Control	38	84	84	2.8	5.5	5.7

In Nigeria the spread of the fungus was recorded in virus-infected trees in plots sprayed with Gamma B.H.C. to control capsids and in unsprayed plots. Capsids were not numerous in the unsprayed plots but were a debilitating factor. In one series of experiments the total spread of die-back recorded in 10 virus-infected trees in an unsprayed plot was 90 per cent. greater than in 10 non-infected trees in an adjacent sprayed plot, and in another series of experiments the spread of die-back in the virus-infected unsprayed trees, was 100 per cent. more than on non-infected sprayed trees.

SEKA.

